TECHNICALLY SPEAKING

BY HAROLD KINLEY

Predicting coverage area is critical

But propagation-measurement software makes a complicated task easier, more accurate

Early in the evolution of land mobile radio, it was discovered that the higher the base-station antenna, the greater the radio coverage area. This sent land mobile radio system engineers looking for higher ground and taller towers.

Predicting radio coverage area is an important aspect in the design of a land mobile radio system and proper placement of the base station(s). If the earth were a perfectly smooth sphere, with equal signal attenuation in all directions, such predictions would come down to a simple formula and the plot of the coverage area would be a perfect circle.

But the earth is not perfectly smooth, so radio coverage from a base station to a mobile unit (located anywhere in the coverage area) generally involves plane-earth propagation. In free-space propagation, the path loss increases six decibels (dB) per octave of distance. For example, at a distance of five miles between two dipole antennas operating at a frequency of 160 MHz, the path loss is 90.3 dB. If the distance is doubled to 10 miles, the path loss becomes 96.3 dB. For plane-earth propagation, the path loss increases by 12 dB per octave of distance.

In *Land Mobile Radio Systems, 2nd edition*, author Edward Singer describes a formula for calculating radio range based on the "modified Egli method" (p.201). This formula is based on 90% probability of communication (see Figure 1).

When using the formula, pay close attention to arithmetic signs and treat them algebraically. For example, the receiver sensitivity (S) is expressed in dBW and this will be a negative figure. The minus sign in front of the S in the formula will change this to a positive value. Since this is such a long formula, it is somewhat unwieldy to handle on a calculator. A computer program that runs under DOS or a DOS window can be obtained by e-mailing me at halkinley@charter.net. An example of how to use the formula is in Figure 2.

Plugging the data from Figure 2 into the formula yields a distance (D) of 20.3 miles. It is important to note that the transmitter antenna height used in the formula is "effective height." Effective height is the ground elevation of the tower site plus the height of the antenna, minus the average terrain elevation. In order to calculate this, the HAAT (height above average terrain) must be known.

The HAAT is calculated as shown in Figure 3. Concentric circles are drawn on a topographic map at two-mile increments from the transmitter site, to a

Figure 1

$$D = \textit{anti}\log\left[\frac{(P_T + G_T + G_R - L_{TT} - L_{RT} - L_P - L_N - 117 - S + 20\log H_T H_R - 20\log F)}{40}\right]$$

D = estimated range, in miles
P_T = base transmitter power, in dBW (decibels referenced to 1 watt)
G_T = base transmitter antenna gain, in dBd (referenced to half-wave dipole)
G_R = mobile antenna gain, in dBd
L_{TT} = base antenna transmission line loss, in dB
L_{RT} = mobile antenna transmission line loss, in dB
L_P = reliability degradation factor, in dB
L_N = noise degradation, in dB
S = mobile receiver sensitivity, in dBW
H_T = base station antenna height above average terrain, in feet
H_R = mobile antenna height, in feet
F = frequency, in MHz

Figure 2

Transmitter output (P_T) = 100 W or 20 dBW
Transmitter antenna gain (G_T) = 6 dBd
Receiver antenna gain (G_R) = -1 dBd
Reliability factor (L_P) = 14 dB
Noise degradation (L_N) = 3 dB
Receiver sensitivity (**S**) = -146 dBW
Effective height of transmitter antenna (H_T) = 175 feet
Height of receiver antenna (H_R) = 6 feet
Frequency (**F**) = 150 MHz

distance of 10 miles. Then, eight radials are drawn at an angular spacing of 45 degrees from the transmitter site to intersect the 10-mile circle. These eight radials are called the cardinal radials. At the point where a radial intersects a circle, the elevation is taken—there are 40 such points.

Then, the 40 elevation readings are added together and then divided by 40 to yield the average terrain elevation around the transmitter site. The elevation of the transmitter site plus the height of the antenna above ground minus the average terrain elevation, is equal to the HAAT of that antenna.

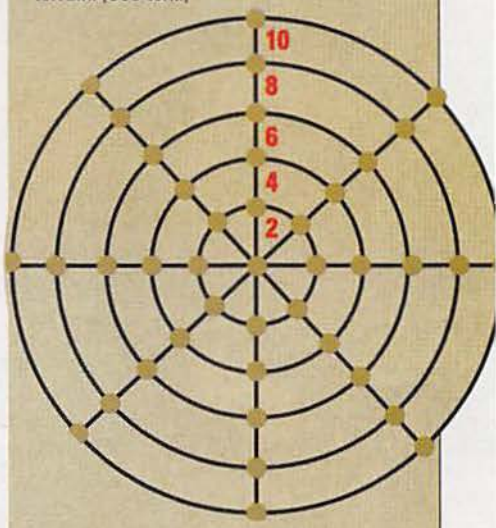
Some interesting points can be gleaned from the formula. The range varies as a function of the square root of the multiplication factor of the effective height of the antenna. For example, if the effective height of the antenna is quadrupled, the range will double . In our example, the tower height must be increased to 675 feet in order to quadruple the effective antenna height. This would double the range to 40.6 miles.

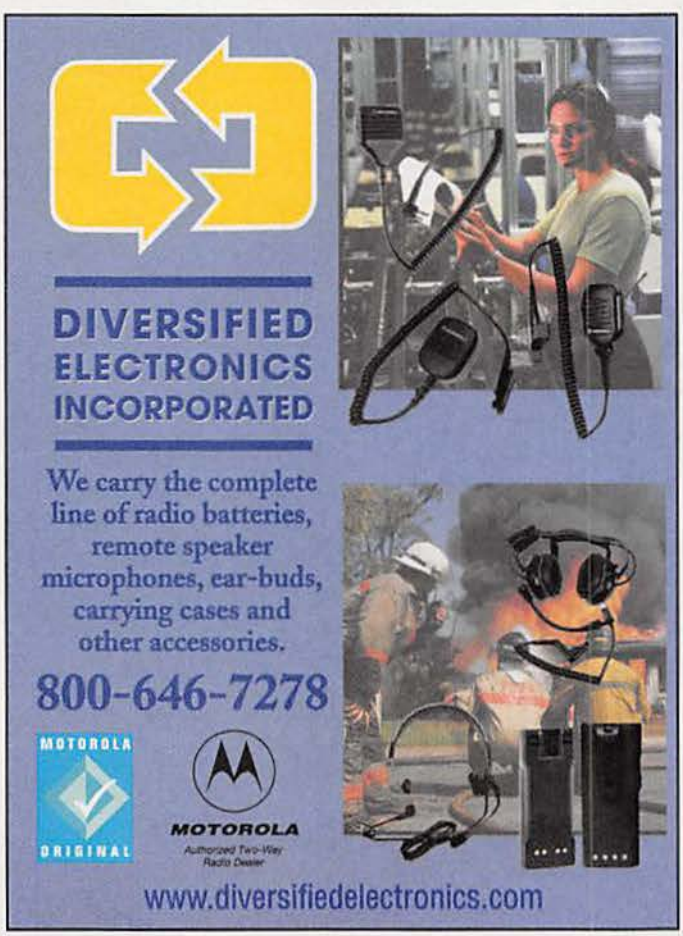
Another way the range can be doubled is by adding 12 dB of gain somewhere, by reducing the losses by 12 dB, or by employing a combination of the two. For example, the transmitter power could be quadrupled (for a 6 dB gain) and the antenna gain increased by 6 dB to yield a total system gain of 12 dB. Theoretically, this would have the same effect as increasing the effective antenna height by a factor of four. However, it may not always work out that way in practice.

In some locations, the terrain might approach that of a smooth sphere. However, much of the earth involves very irregular terrain, from gently rolling hills to very rugged mountains. In order to achieve any significant degree of accuracy in the prediction of

Figure 3

The elevation at the points where the cardinal radials intersect the circles are added together and divided by the number of points (40) to determine the height of the average terrain. (See text.)





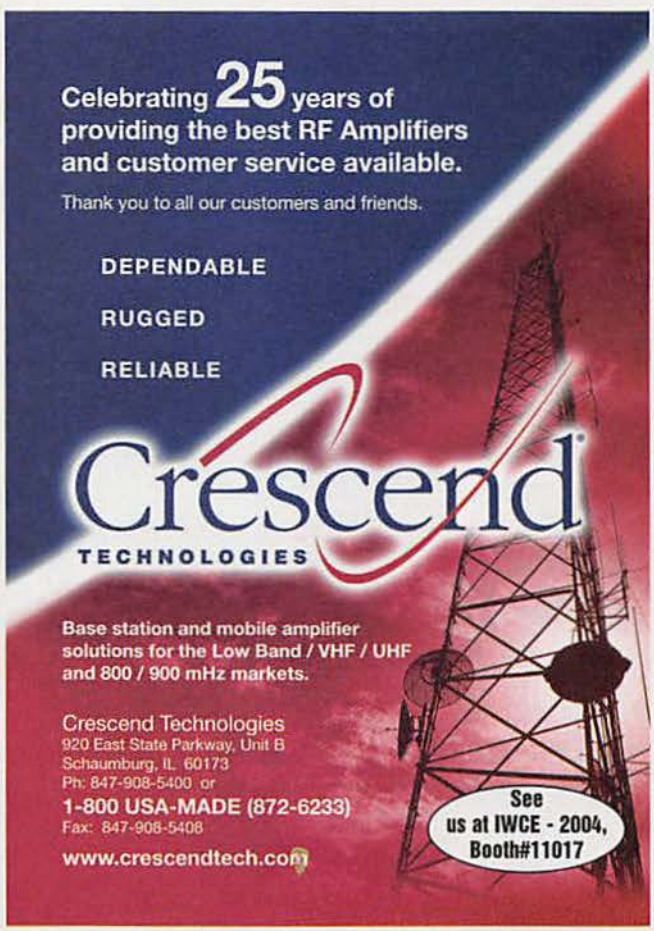

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Figure 4: Two radio coverage plots are shown, one on top of the other and overlaid on a map to compare coverage using different signal strengths.

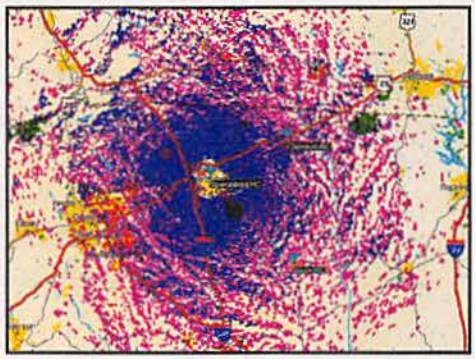
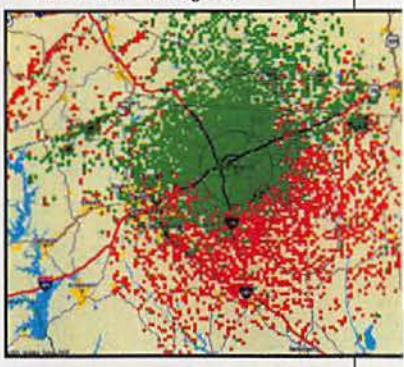


Figure 5: Here, the coverage from all three base stations in the network are combined into a single plot. A mobile unit anywhere in the green area should be able to receive at least one of the base stations in the network.

Figure 6: This plot shows areas (red) where the desired signal (green) is less than 6 dB above the undesired signal.



radio coverage, the terrain of the coverage area must be taken into account. This involves such a tremendous amount of calculations that computer programs have been developed to handle the task. The Egli model, the Bullington model and the Longley-Rice model are the three most commonly used range-prediction models.

Radio Mobile Deluxe[1] is propagation study software based on the Longley-Rice[2] propagation model that assesses irregular terrain in the frequency range of 20 MHz to 20 GHz. This free software can be downloaded from http://www.cplus.org/rmw/english1.html. (The basis for this software can be found at http://elbert.its.bldrdoc/itm.html.) Radio Mobile Deluxe provides an excellent Windows-based

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interface between users and the Longley-Rice propagation model. In order to use the program, you must have terrain elevation data. The one arcsecond (30 meter) database provides excellent resoluion and can be obtained from several sites. One is ftp://edcsgs9.cr.usgs.gov/pub/data/srtm/United_States_1arcsec/1arcsec. (Don't omit the underscores when typing in this Web address.)

In addition, good information on the ITS irregular terrain model can be found in the NTIA Report 82-100, *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode*, April 1982.[3] The NTIA's Web address is http://www.ntia.doc.gov.

While this column doesn't have the space to provide a complete tutorial on running the Radio Mobile Deluxe software, a few sample coverage plots illustrate some of its capabilities. Figure 4 shows two plots over the same map. The lighter colored plot was based on a received-signal level of one microvolt. The darker plot was based on a received-signal level of three microvolts. This allows the user to determine the effect of system changes on the coverage area.

The radio network depicted in Figure 4 consists of three base stations. The plot in Figure 4 is for the Spartanburg, S.C., station only. The software will produce plots that combine the coverage of any or all of the stations in a network. Figure 5 shows the combined plot of all three stations in the network. The green plot indicates that a mobile unit anywhere in the green area should be able to communicate with at least one of the base stations in the network.

Figure 6 shows a plot that indicates areas of interference (red) where the desired signal (green) is less than 6 dB above the undesired signal. The signal-to-interference ratio (S/I) can be set to other values in the software.

These plots were done using the one-arcsecond terrain elevation database. The plots were overlaid on a map from MapBlast. The Radio Mobile Deluxe software has many other features that are too numerous to describe, or even list, here. Remember that while no propagation software is 100% foolproof, sensible input will provide useable output.

Until next time—stay tuned! ■

[1] Radio Mobile Deluxe is freeware developed by Roger Coudé of Canada.
[2] Longley-Rice is named for Anita Longley and Phil Rice.
[3] NTIA is the National Telecommunications and Information Administration.

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ference. Interference limits and disputes would be resolved within a "spectrum court" system, with damages for radio interference having to be proved and compensation awarded should interference be demonstrated.

Open commons advocates are likely to find themselves in conflict with the wishes of Congress. According to Lauren Patrich, spokeswoman for the FCC's Wireless Telecommunications (WTC) Bureau, the Auction Reform Act of 2002 directed the FCC to conduct auctions of the 700 MHz band before the expiration of the commission's auction authority on September 30, 2007. Auctioning of the lower 700 MHz band was conducted in late August through early September 2002. The 102 winning bidders paid more than $88 million dollars for 484 licenses around the country.

Dates for the upper 700 MHz band auction haven't been set, because the commission first wants to complete open proceedings concerning digital television and third-generation wireless services, said Peter Tenhula, acting bureau chief and director of the FCC's Spectrum Policy Task Force.

Public-safety organizations are lobbying hard for a chunk of upper 700 MHz spectrum. The Spectrum Coalition for Public Safety wants Congress and the FCC to stop the upper 700 MHz auction and allocate a total of 10 MHz of spectrum in the 700 MHz band for public safety and homeland security use. Further, they would like to see a "no-strings" mandate for TV broadcasters to clear the 700 MHz spectrum by Jan. 1, 2007. ■

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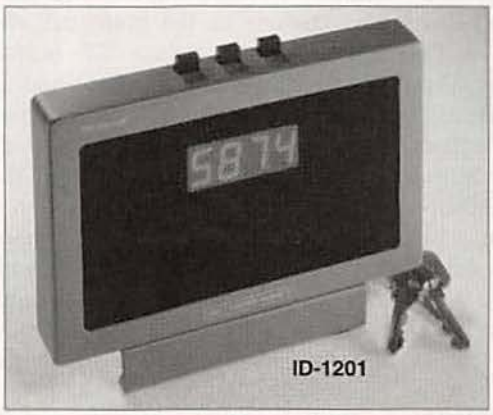

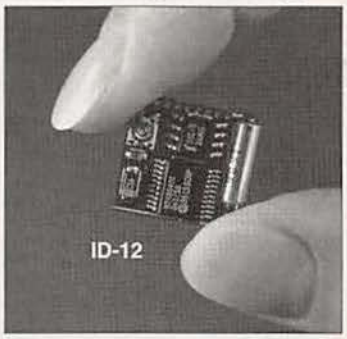

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